

Senior Thesis

Comparison of data from an laboratory exercise for Geological Sciences 245, Computational Geology, to resurfacing models for Venus.

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2000

Submitted as partial fulfillment of the requirements for the degree of Bachelor of Science in Geological Sciences at The Ohio State University,
Autumn, 2000

SEN: GEA
2000
M377

Approved by:



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There are two resurfacing models for Venus, catastrophic resurfacing model and equilibrium-resurfacing model, put forward by Phillips et al. (1992). In this paper I compare data that I collected for a laboratory exercise I wrote to these models. The lab exercise uses craters density to compare to the resurfacing models. The results are unclear because of the limited scope of the data that the laboratory exercise examines.

1. Introduction

Impact Craters have been used to estimate ages on many planetary bodies. Venus and the Moon are only two bodies where craters have been use to estimate ages. On Venus craters have been used extensively for age dating because of a lack of situ samples for age dating. The primary ways that craters have been used are by taking crater density counts. The crater densities have been used to formulate several models for Venus' geologic history. Using the models many researchers believe that Venus' surface is young and that Venus has under gone extensive resurfacing (Phillips et al., 1992). It is believed that resurfacing of Venus happened on a nearly global scale, and happened over a rather short time scale (Phillips et al., 1992). Based on this information I designed a lab exercise for Geological Science's coarse 245, Computational Geology, at The Ohio State University. This paper will compare the data collected for the lab exercise to some resurfacing models.

1. Overview of Venus and its Craters

The Magellan Mission provided a great deal of knowledge on Venusian craters including size, location, and morphology. Using imaging radar Magellan mapped most of Venus' surface. The majority of the craters on Venus are well preserved, with many in pristine condition. In fact only 17% of Venusian impact craters are "modified" (Phillips et al., 1992). Phillips et al. (1992) divided "modified" craters into two categories, embayed craters and craters that are tectonically disturbed. Embayed craters are craters that have been breached by lava flows.

Impact crater density data have been used on Venus because conditions on Venus hamper other methods that have been used on other planetary bodies. Some of the methods used on other planetary bodies were in situ rock samples, on the Moon, and size-distribution test of impact craters. Lack of technology prohibits in situ rock sampling. Venus' thick atmosphere decreases the number of small diameter craters that are created, forcing size-distribution test to be used on larger craters reducing a small data set into a smaller one, making these data statistically questionable. The crater density is obtained by totaling the number of craters then dividing that number by the area, given in kilometers squared. These densities were then applied to several models to obtain an age estimate for Venus' surface age.

There are several models used to determine how Venus' global resurfacing event occurred. This paper will explore two end member models put forward by Phillips et al. (1992). Both models assume that Venus' surface is relatively young. This is supported by the fact that most Venusian craters are in near pristine condition and that there are relatively few impact craters on Venus, compared to other planetary bodies. Also both models assume that craters are randomly distributed across the surface of Venus. Randomness of crater impacts has been suggested by Fielder (1966) for the moon and Arvidson et al. in 1990.

The first model is the catastrophic resurfacing model; this model states that the entire surface of Venus was resurfaced in one quick global resurfacing event. The catastrophic resurfacing model assumes that impact craters are created at a constant rate and that all visible craters formed after the resurfacing event. Phillips et al. (1992) came to the conclusion that this model had shortcomings on both a statistical level and a geologic level. On a statistical level the model came up short because of the number of modified craters to unmodified craters was not correct. On a geologic level there is evidence that resurfacing occurred at different times at different locations. The second model put forward by Phillips et al. (1992) is the equilibrium-resurfacing model. The equilibrium

resurfacing model states that Venus has been resurfacing at an average rate over time. The rate that Phillips et al. (1992) assumed was $1 \text{ km}^2 \text{ yr}^{-1}$. The advantage of this model is that it allows for different ages in different areas. This model also has some shortcomings. On a statistical level the data are inconsistent with the number of modified craters on Venus. On a geologic level this model works well for volcanic regions. It is likely that the way resurfacing on Venus works is a combination of these two models, catastrophic resurfacing on a local scale at some locations, and equilibrium resurfacing at or near volcanic regions.

3. Brief Overview of the Lab Exercise

The purpose of lab exercises in the Geological Science 245 class is to familiarize students with Matlab and its statistical applications. A copy of the lab can be found in appendix A. This lab was designed so it could be finished in a few hours of laboratory work. The student will have to already know some Matlab programming. These two facts make this lab exercise ideal for being assigned near the end of the course. This will allow students to catch up on earlier assignments, and give the grader of the labs a short lab to grade. The purposes of this lab are to use the χ^2 test, using histograms and the corresponding Matlab commands, and to have students interpret results of the exercise.

The lab exercise consists of two main parts. The first part is to obtain crater density from three pictures of three different regions on Venus. While this is a relatively easy job the interpretation of this data is used later in the lab to answer some questions. The second part of this lab is a comparison of crater diameters on Venus to crater diameters on the Moon. The reason for including lunar crater data in this lab for comparison is to help the student see the effect of the Venusian atmosphere on crater size, which is easier to see with the comparison of histograms of the two data sets. This is the part of the lab where Matlab programming is used. The programming is used to make the histograms that are to be used in the comparison and to perform the X^2 test.

4. Study Areas

The lab used three photographs of different areas of Venus. The first photograph was of Imdr Regio (Figure 1, Herrick, Venus Crater Database). Imdr Regio is thought to be a volcanic highland, consisting mostly of volcanic plains. The volcanoes of Imdr Regio are thought to have been caused from a hotspot in the Venusian mantle (Bougher, Hunten, and Phillips, 1997). The location of the photograph is 195° to 240° E longitudes and -40° to -20° S latitudes.

An area near Ovda Regio (Figure 2, Herrick, Venus Crater Database) is the second photograph in the lab. The area

photographed is to the east of Ovda Regio. This area shows signs of tectonic activity, which is faulted and shows some offsetting. The location of this photograph is 105° to 150° E longitudes and 0° to -20° S latitudes.

The last photograph is of Western Eistla Regio (Figure 3, Herrick, Venus Crater Database). The Western Eistla Regio consists mostly of volcanic highlands with a prominent fracture zone striking north by northeast - south by southwest (Grimm and Phillips, 1992). The region consists of shield volcanoes and a rift system (Grimm and Phillips, 1992). The location of the photograph is -30° to 15° W longitudes and 0° to 20° N latitudes.

5. Detail Explanation of the Lab

The first thing to do in the lab is to obtain the Matlab files and data files. The two Matlab files **craterplot.m** and **cratermoon.m** are used to convert the data in the two data files into useable data for Matlab. Both Matlab files were written by Tim Leftwich, Ohio State University. Copies of both **craterplot.m** and **cratermoon.m** are included in Appendix A. The moon data set consists of 1558 diameters obtained from Gazetteer of Planetary Nomenclature (2000). The Venusian data set was obtained from an earlier lab for Geology 245.

The second question of the lab asks the student to count the craters in each of the photographs, and then use those numbers

to obtain a crater density for each of the three areas. The estimation that one degree is equal to about 105.6420 km is given, making the area of the photographs about 10,044,209km each. The results for question two are

Area	Crater Count	Crater Density (#/km ²)
Imdr Regio	16	1.89×10^{-6}
Ovda Regio	28	2.79×10^{-6}
Western Eistla Regio	40	3.982×10^{-6}

Question three asks the student to estimate ages for the three areas. To do this the crater densities are divided by the global crater density of about $1.96 \times 10^{-6}/\text{km}^2$ (from earlier lab) to obtain a ratio, this ratio is then multiplied by the mean surface age for Venus, between 288 Myr and 800 Myr. This results in two different age estimates for each study area. The results for question three are

Area	Age estimate for 288 Myr (in Myr)	Age estimate for 800 Myr (in Myr)
Imdr Regio	277.7	768.0
Ovda Regio	410.0	1.136×10^3

Western Eistla	584.6	1.624×10^3
Regio		

In the fourth question students are asked to plot four histograms from the crater diameter data sets. They are to plot two different histograms for each data set; the histograms are plotted with two different numbers of bins. The histograms for the Moon data set are shown in figures 4 and 5, and the histograms for the Venus data are shown in figures 6 and 7. The plots with fewer bins show less detail and are misleading (Figure 4 and 6). When the histograms with more bins are plotted greater detail comes out. Looking at the two histograms with 300 bins, the fact that there are no Venusian craters smaller than about 1.3 km and few craters under two or three kilometers (Figure 5 and 7). The student is then asked to determine if the data sets are normally distributed by performing a χ^2 test on the data. When χ^2 test performed on both data sets turns out to not be normally distributed. The reason for this is in the case of Venus is the lack of smaller diameter craters, and an abundance of medium sized craters (diameters between 10km and 30km). For the moon data the reason is that there are an abundance of craters smaller than 80km, if the data were normally distributed there would be fewer small craters.

The fifth question is designed to get the student to think about what the lab data is conveying. The question is broken up into three sections. Part A asks to give an age range for each study area; this is the same data from question three. The second part, B, asks the student to obtain an age range for Venusian resurfacing, by using the three study areas. The usefulness of this part is limited because there are only three study areas. This results in an age range between 307.3 Myr and 856.0 Myr. This is consistent with the 0.5 Ga that Phillips et al. suggested for the catastrophic resurfacing model. This part also asks the student to obtain a percentage of Venus' age that resurfacing occurred in, assuming Venus is 4.6 Byr (The age of the solar system). The results for this are 6.68% to 18.6%. This was done so the students can get some kind of idea of how fast resurfacing may have been. The last part of this question asks the student to use the histograms to interpret the effects of Venus' atmosphere on crater diameters, as stated earlier the atmosphere stops craters that are smaller than 1.3 km from forming and limits the number of small craters. The reason this is in the lab is that both resurfacing models use craters with diameters of 35 km or larger, to negate the effects of Venus' atmosphere.

6. Limitations of the Lab and Resurfacing models

The biggest limitation for the resurfacing models is that there is only one Venus. There are no other objects that we know about that have properties similar to Venus, so any comparisons to other planetary bodies have limitations. Another limitation is the absence of in situ samples. Another limitation is that both resurfacing models are idealized end members, so neither can be absolutely correct. Neither resurfacing model takes into account that as solar debris contacts with a planetary body that debris is destroyed, so over time the amount of free material in the solar system decreases. The fact that the resurfacing models happen in a small time period, around 500 Ma, makes the amount of lost material minuscule.

The major limitation for the lab is the amount of data used, with only three study areas that cover only a small area of the planet.

7. Results

The lab exercise supports a resurfacing model somewhere between the two models proposed by Phillips et al. (1992), because the age ranges are different for each area but still similar to each other. If the catastrophic resurfacing model were correct the ages for the study areas would all be similar. Resurfacing on Venus most likely happened very fast for sections of the planet but not the planet as a whole. In volcanic regions the

resurfacing probably happened at a consistent rate like in the equilibrium resurfacing model. As the lab is limited in the data that it examines compared to Phillips et al. paper (1992), which uses data about crater morphology, crater density on a global scale, and crater locations. The amount of data that Phillips et al. (1992) use creates a more complete argument on resurfacing of Venus.

References

- Arvidson, R.E., R.e. Grimm, R.J. Phillips, G.G. Shoemaker, and E.M. Shoemaker, On the nature and rate of resurfacing of Venus, *Geophys. Res. Lett.*, 17, 1385-1388, 1990.
- Bougher, S.W., D.M. hunten, and R.J. Phillips (editors), *Venus II, Geology, Geophysics, Atmosphere and Solar Wind Enviroment*, University of Arizona Press, Tucson, Az, 1997.
- Fielder, G., Test for randomness in the distribution of lunar craters, *Mon. Not. R. Astron. Soc.*, 132, 413-422, 1966.
- Gazetteer of Planetary Nomenclature, <http://www.flag.wr.usgs.gov/USGSFlag/Space/nomen/nomen.html>, update: August 31, 2000.
- Grimm, R.E., and R.J. Phillips, Anatomy of a Venusian hot spot: Geology, gravity, and mantle dynamics of Eistla Regio, *J. Geophys. Res.*, 97, 16,035-16,054, 1992.
- Herrick, R.R., Venus Crater Database, <http://www.lpi.usra.edu/research/vc/vchome.html>, update unknown.
- Phillips, R.J., R.F. Raubertas, R.E. Arvidson, I.C. Sarkar, R.R. Herrick, N. Izenberg, and R.E. Grimm, Impact Craters and Venus Resurfacing History, *J. Geophys. Res.*, 97, 15,923-15,948, 1992.

Appendix A. Laboratory Exercise for Geology 245.

CRATER STATISTICS OF VENUS AND THE MOON

Purpose:

Using the X^2 test, using histograms, and interpreting results.

Description

This lab will look at two planetary bodies with two very different geological histories. One of these bodies is the planet Venus and the other is Earth's moon (Luna). Compared to the other inner planets Venus has few craters. The craters on Venus appear to be young and pristine. By comparison the Moon is heavily cratered and its craters are in varying states of weathering.

The appearance of the craters on Venus suggest a global resurfacing event. Some observers have suggested that the resurfacing event took place between 300 to 1000 Ma. The surface of Venus shows signs of volcanic and tectonic reworking. This data plus the crater data support the resurfacing model. Some observers suggest that the resurfacing may still going on, but at a slower rate.

The Moon shows no sign of tectonic activity and little erosion. Most of the craters on the Moon are thought to have formed early on in the solar system's history. During a period of heavy bombardment, when there was more "loose solar material" traveling around the solar system. So the Moon craters are thought to be older than the craters on Venus. The cratering on the Moon is still going on.

This lab will focus on three areas on Venus (Imdr Regio, Ovda Regio, and Eistla Regio). Imdr Regio is a highland area made up of mostly Volcanic plains. Imdr Regio is located near 40°S; 240°E. The next area is located to the east of Ovada Regio. This region is a region that shows evidence of tectonic activity. The study area is located at 10°S; 125°E. The last area is located to the west of Eistla Regio. Eistla Regio is a lava flow and rift valley. The study area is located around 0°N; 20°E.

Report:

1. Obtain files **craters.dat** and **mooncrat_j.dat** and the programs **craterplot.m** and **cratermoon.m**.
2. The global crater density is $\cong 1.96 \times 10^{-6}/\text{km}^2$. Estimate the crater density for the three study regions, the pictures are included in this lab. To obtain the area a good estimate is one degree is equal to about 105.6420 km. The formula below may give you better results. Report your results.

$$A = \rho^2 \sin \phi d\phi d\theta.$$

3. Find a ratio for each of the study areas compared to the global density. To obtain an estimate of the age of the area, multiply each ratio by the mean surface age for Venus. The mean surface age of Venus has been estimated to be between 288 Myr to 800 Myr. Report your answers for both 288 Myr and 800 Myr.
4. Perform a histogram analysis on both sets of crater diameter data (**hist** in MATLAB command), programs **craterplot.m** and **cratermoon.m**. On both histograms use 25 and 300 bins. Plot the related normal probability density function using values determined at the peaks, $\pm 1\sigma$, $\pm 2\sigma$, and $\pm 3\sigma$ (for both data sets). Determine if the crater diameter data sets are normally distributed by performing a χ^2 analysis between the expected number of observations and the actual number.
5. Answer the follow questions. a) What is the estimated age of Imbr Region, Ovda Regio, and Eistla Regio? Remember to multiply the ratios from part 3 by the mean surface age of Venus. b) Give the range for time that global resurfacing took, and give the percentage of Venusian history this occupied. (assume Venus' age is 4.6 Byr) c) What effect could the thick atmosphere of Venus have on the crater data, compare the histogram of Venus' crater diameters to the histogram of the moon crater diameters (hint: look at the small diameter crater)?

REMEMBER TO HAND IN ALL YOUR INPUT/OUTPUT FILES

Copy of **cratermoon.m** Matlab file.

```
%This function reads the crater database and plots the craters...
%it also creates the diameter database. You can add your own
%commands to facilitate analyzing the data.

function[figure]=craters(in)
test='c';
fid=fopen('mooncrat_j.dat');

for k=1:1558

    %test=fscanf(fid,'%s',1);
    i=1;
    while test ~= ' '
        test=fscanf(fid,'%c',1);
        name(i)=test;
        i=i+1;
    end

    lat=fscanf(fid,'%f',1);
    test=fscanf(fid,'%c',1);
    long=fscanf(fid,'%f',1);
    test=fscanf(fid,'%c',1);
    diameter=fscanf(fid,'%f',1);

    %lat
    %long
    diameter

    i=1;
    test='c';
    while test ~= '\n'
        test=fscanf(fid,'%c',1);
        garbage(i)=test;
        i=i+1;
    end

    %elevation=fscanf(fid,'%f',1);
    %test=fscanf(fid,'%c',1);
    %count=k
    lats(k,1)=lat;
    longs(k,1)=long;
    DIAMETERS(k,1)=diameter;      %OK kids these are your diameters!!!!
end

Z=ones(size(lats))*400;

%plot3(longs,lats,Z,'*','Color','r');

%figure
hist(DIAMETERS,30)

%max_Diameter=max(DIAMETERS)
%min_Diameter=min(DIAMETERS)
%mean_Diameter=mean(DIAMETERS)
%standdev_Diameter=std(DIAMETERS)
```

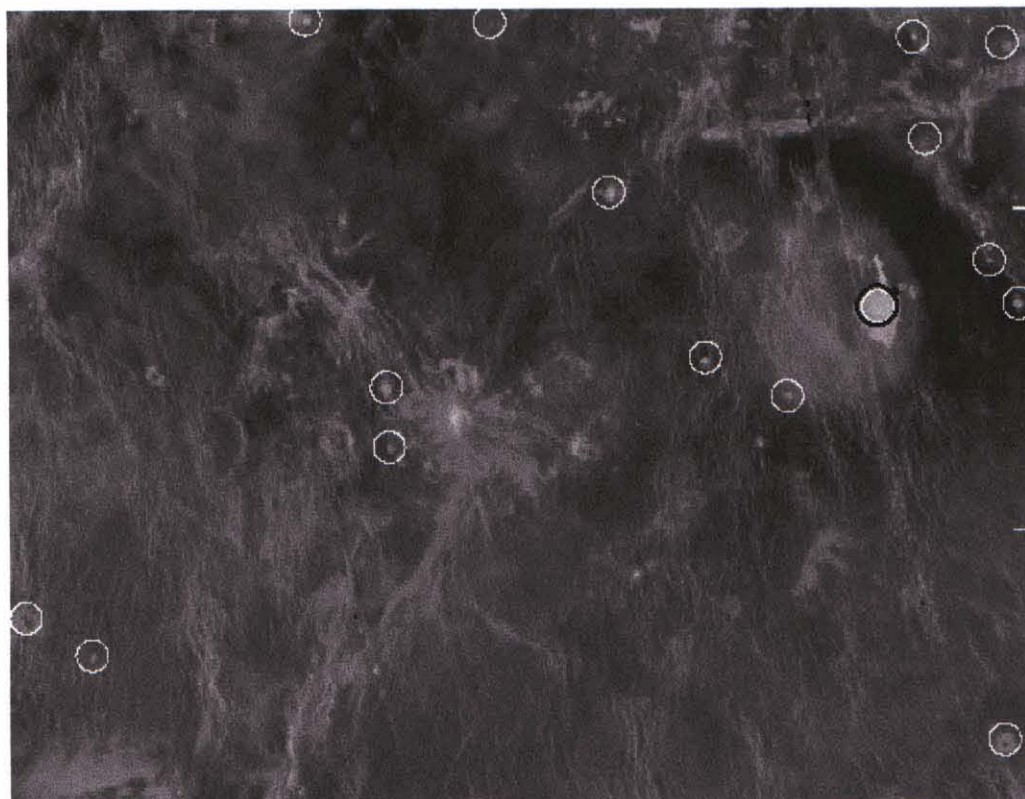



Figure 1. Photograph of Imdr Regio with craters marked on it. Located at longitude 195 to 240 and latitude -40 to -20.

(Source: Venus Crater Database,
<http://www.lpi.usra.edu/research/vc/vchome.html>)

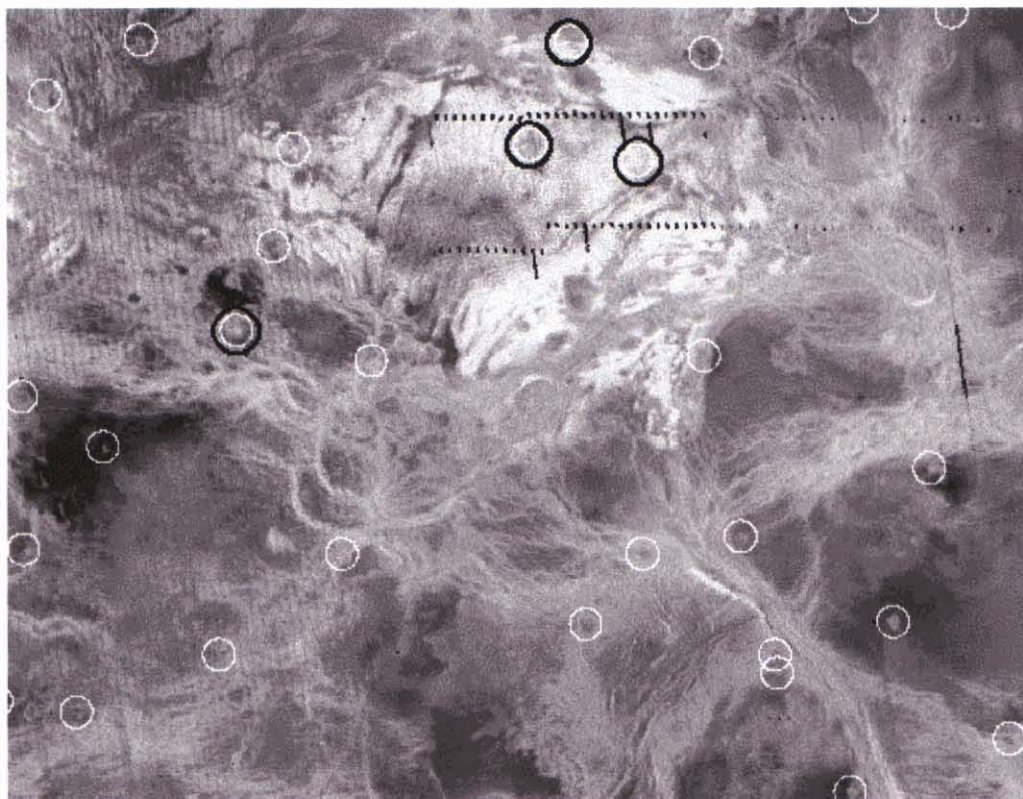


Figure 2. Photograph area east of Ovda Regio with craters marked on it. Located at longitude 105 to 150 and latitude 0 to -20.

(Source: Venus Crater Database,
<http://www.lpi.usra.edu/research/vc/vchome.html>)

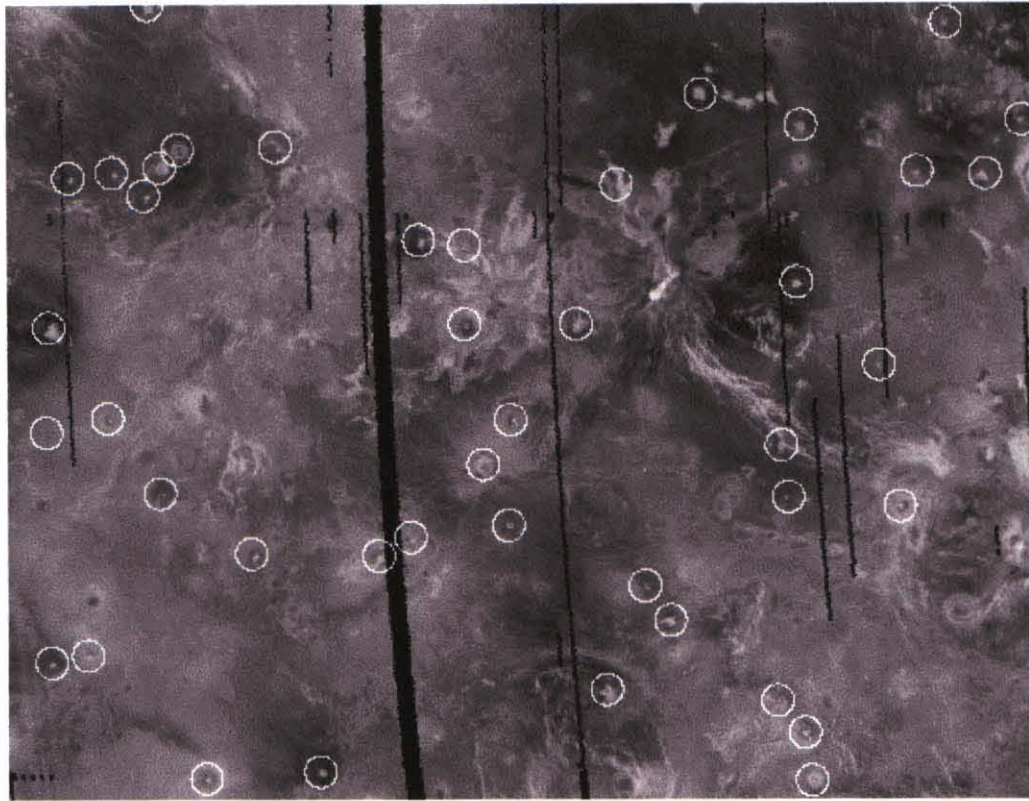


Figure 3. Photograph of Western Eistla Regio with craters marked. Located at longitude -30 to 15 and latitude 0 to 20.
(Source: Venus Crater Database,
<http://www.lpi.usra.edu/research/vc/vchome.html>)

Figure 4. Moon 25 bins

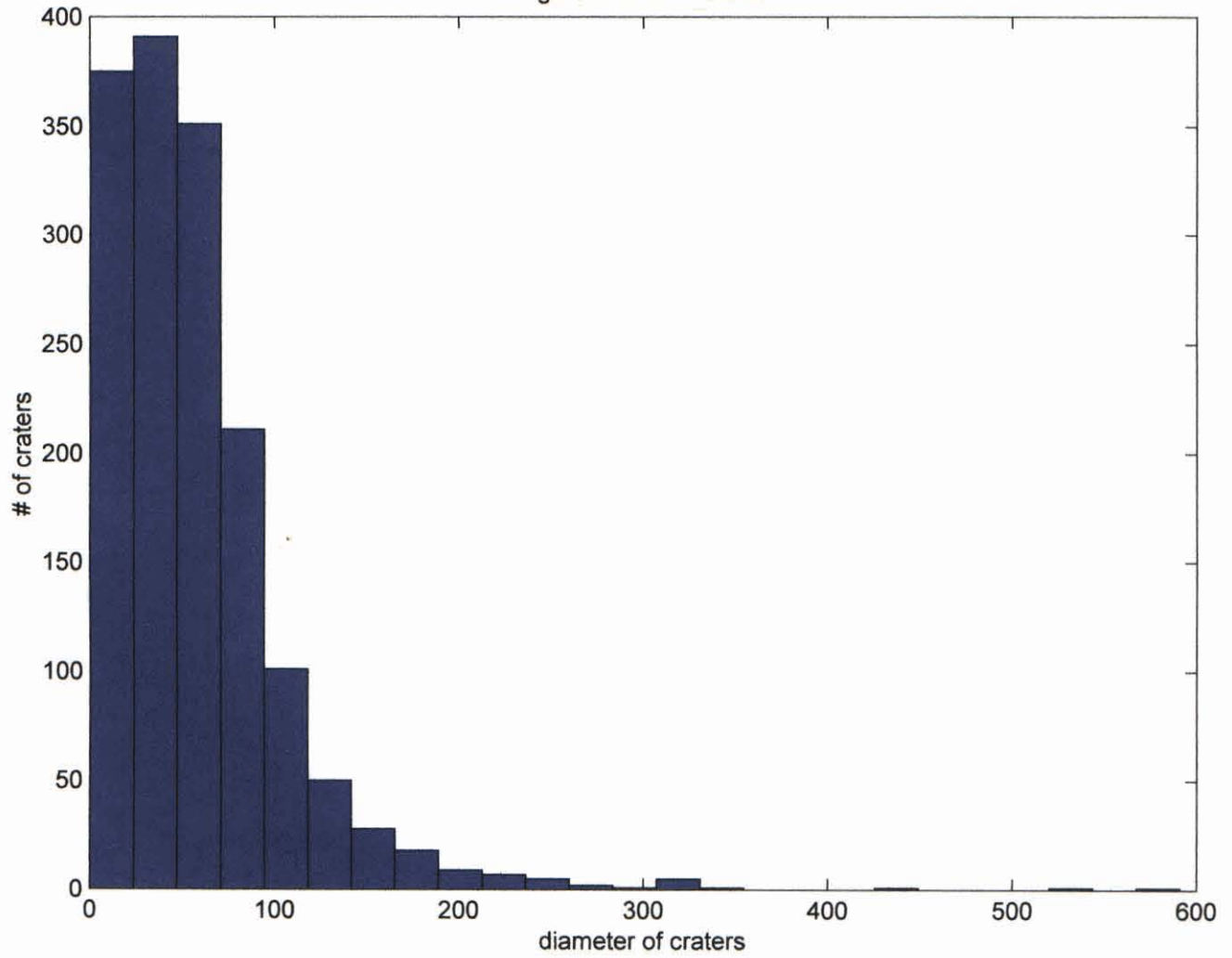


Figure 5. Moon 300 bins

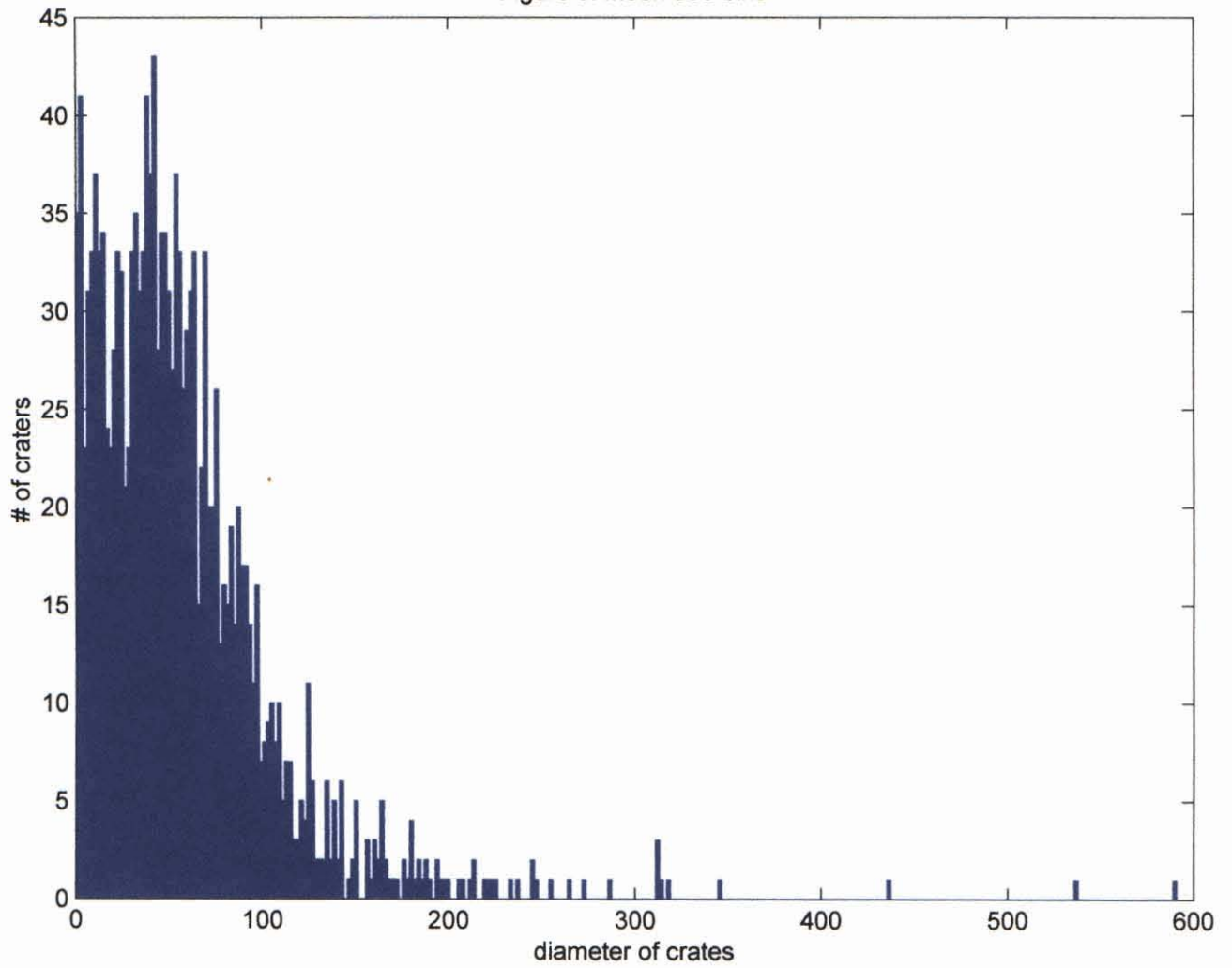


Figure 6. Venus 25 bins

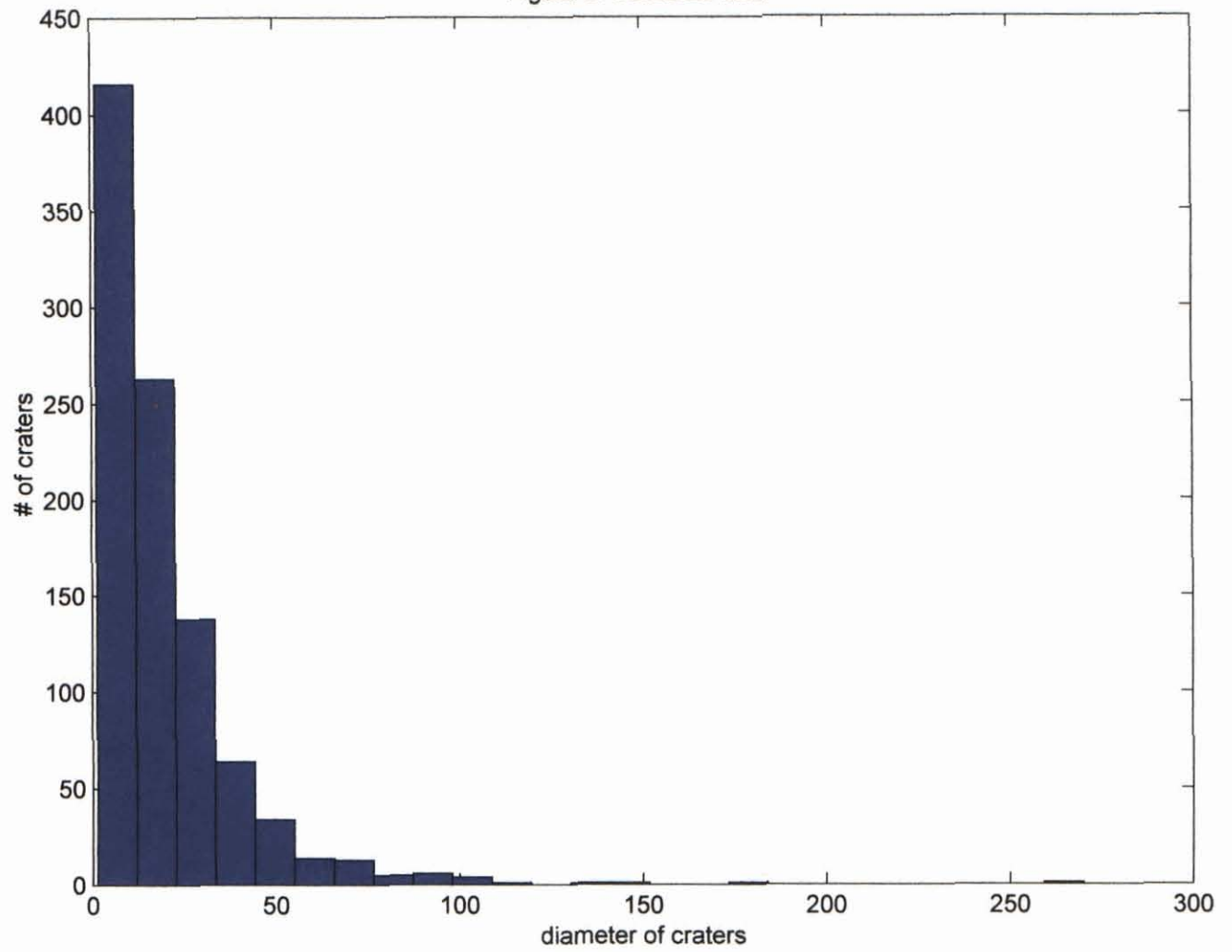


Figure 7. Venus 300 bins

